CLAIMS

WE CLAIM:

1. A network-independent, high-reliability communications system for an industrial controller using a standard serial communications network, the communications system comprising:

a first I/O communications circuit receiving I/O data for control of an industrial process;

a first network-independent protocol device receiving the I/O data and formatting it for transmission under a network-independent protocol to produce high-reliability formatted data formatted to reduce undetected transmission loop errors;

a first standard network protocol device receiving the high-reliability formatted data and further formatting it for transmission under a protocol of the standard serial communications network, to produce doubly-formatted data for transmission on the standard serial communications network, the protocol of the standard serial communications network also formatting data to reduce undetected transmission loop errors;

a second standard network-protocol device receiving the doubly-formatted data from the standard serial communications network and extracting the high-reliability formatted data according to the protocol of the standard serial communications network;

a second network-independent protocol device receiving the high-reliability formatted data and extracting the I/O data; and

a second I/O communications circuit receiving I/O data for control of an industrial process from the second network-independent protocol device;

whereby high-reliability transmissions may be simply obtained on an arbitrary standard serial communications network protocol.

2. The industrial controller of claim 1 wherein the first and second I/O communications circuits are selected from the group consisting of an industrial controller, an input circuit for an industrial controller, a bridge, and an output circuit for an industrial controller.

3. The industrial controller of claim 1 wherein the first network-independent protocol device formats the I/O data by adding error detection data consisting of: a cyclic redundancy code related to the I/O data and a sequence count related to a local order of transmission of the I/O data with respect to other I/O data being transmitted.

4. The industrial controller of claim 1 wherein the second network-independent protocol device further generates an acknowledgment message upon receipt of the I/O data and formats it under the network-independent protocol to produce a high-reliability formatted acknowledgment data;

and wherein the second standard network protocol device receives the high-reliability formatted acknowledgment data and further formats it for transmission under the protocol of the standard serial communications network, to produce doubly-formatted acknowledgment data for transmission on the standard serial communications network;

and wherein the first standard network-protocol device receiving the doubly-formatted acknowledgment data from the standard serial communications network and extracts the high-reliability formatted acknowledgment data according to the protocol of the standard serial communications network;

and wherein the first network-independent protocol device receiving the high-reliability formatted acknowledgment data checks the data to detect transmission loop errors.

5. The industrial controller of claim 4 wherein the acknowledgment data includes the I/O data and the first network-independent protocol device detects errors by comparing the I/O data to the acknowledgment data.

6. The industrial controller of claim 1 wherein the first network-independent protocol device operates to start a timer upon receipt of the I/O data and wherein the first network-independent protocol device detects errors by checking a time on the timer against an allowable time upon receipt of the acknowledgment message.

7. The industrial controller of claim 1 wherein the first network-independent protocol device transmits I/O data on a regular interval and wherein the second network-independent protocol device detects errors by comparing the time at which the last I/O data was received against the time interval.

8. The industrial controller of claim 1 wherein the second network-independent protocol device evaluates the high-reliability formatted data to detect transmission loop errors of the I/O data and upon the detection of an error for I/O data assume a default safety state of the I/O data.

9. The industrial controller of claim 4 wherein the first network-independent protocol device evaluates the high-reliability formatted data to detect transmission loop errors of the I/O data and upon the detection of an error for I/O data assume a default safety state of the I/O data.

10. The industrial controller of claim 1 wherein the standard serial communications network is selected from the group of networks consisting of Ethernet, DeviceNet, ControlNet, Fire Wire and Field Bus.

11. A method of providing a high-reliability communications system for an industrial controller using a standard serial communications network, the communications system comprising the steps of:

(a) receiving I/O data for control of an industrial process at a first I/O communications circuit;

(b) formatting the received I/O data for transmission under a network-independent protocol at a first standard network protocol device to produce high-reliability formatted data formatted to reduce undetected transmission loop errors;

(c) receiving the high-reliability formatted data at a first standard network protocol device and further formatting it for transmission under a protocol of the standard serial communications network, to produce doubly-formatted data for transmission on the standard serial communications network, the protocol of the standard serial communications network also formatting data to reduce transmission loop errors;

(d) receiving the doubly-formatted data from the standard serial communications network at a second standard network-protocol device and extracting the high-reliability formatted data according to the protocol of the standard serial communications network;

(e) receiving the high-reliability formatted data at a second network-independent protocol device and extracting the I/O data; and

(f) receiving I/O data for control of an industrial process from the second network-independent protocol device at a second I/O communications circuit;

whereby high-reliability transmissions may be simply obtained on an arbitrary standard serial communications network protocol.

12. The method of claim 11 wherein at step (b) the first network-independent protocol device formats the I/O data by adding error detection data selected from the group consisting of: a cyclic redundancy code related to the I/O data and a sequence count related to a local order of transmission of the I/O data with respect to other I/O data being transmitted.

13. The method of claim 11 including the further steps of:

(e) generating a reply message by the second network-independent protocol device upon receipt of the I/O data formatted under the network-independent protocol to produce a high-reliability formatted acknowledgment data;

(f) receiving the high-reliability formatted acknowledgment data at the second standard network protocol device and further formatting it for transmission under the protocol of the standard serial communications network, to produce doubly-formatted acknowledgment data for transmission on the standard serial communications network;

(g) receiving the doubly-formatted acknowledgment data from the standard serial communications network at the first standard network-protocol device and extracting the high-reliability formatted acknowledgment data according to the protocol of the standard serial communications network; and

(h) receiving the high-reliability formatted acknowledgment data at the first network-independent protocol device to detect transmission loop errors.

14. The method of claim 13 wherein the acknowledgment data reflects the I/O data and wherein at step (h) the first network-independent protocol device detects errors by comparing the I/O data to the acknowledgment data.

15. The method of claim 11 wherein at step (b) the first network-independent protocol device starts a timer upon receipt of the I/O data and wherein at step (h) the first network-independent protocol device detects errors by checking a time on the timer upon receipt of the acknowledgment message.

16. The method of claim 11 wherein at step (b) the first network-independent protocol device transmits I/O data on a regular interval and wherein at step (e) the second network-independent protocol device detects errors by comparing the time at which the last I/O data was received against the time interval.

17. The method of claim 11 wherein at step (e) the second network-independent protocol device uses the formatting of the first network-independent protocol device to detect transmission loop error in transmission of the I/O data, and upon the detection of an error for I/O data to assume a default safety state of the I/O data.

18. The method of claim 13 wherein the first network-independent protocol device evaluates the high-reliability formatted data to detect transmission loop errors of the I/O data and upon the detection of an error for I/O data assume a default safety state of the I/O data.

19. The method of claim 11 wherein the standard serial communications network is selected from the group of networks consisting of Ethernet, DeviceNet, ControlNet, Fire Wire and Field Bus.